AD-A050 288 NEW MEXICO STATE UNIV UNIVERSITY PARK DEPT OF PSYCHOLOGY F/G 5/5
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INPUT AND OUTPUT PROCESSES IN THE STROOP PHENOMENON

Evelyn Williams

TECHNICAL REPORT 77-3

November 1977

Sponsored by AFOSR F44620-76-C-0013
Warren H. Teichner, Principal Investigator

[redacted]

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

18 19 **REPORT DOCUMENTATION PAGE**

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: AFOSR TR-78-0139

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER: 9

4. TITLE (and Subtitle): 6 Input and Output Processes in the Stroop Phenomenon

5. TYPE OF REPORT & PERIOD COVERED: Interim Technical Report.

6. PERFORMING ORG. REPORT NUMBER: 14 NMSU-AFOSR-TR-77-3

7. AUTHOR(s): 10 Evelyn Williams

8. CONTRACT OR GRANT NUMBER(s): 15 F44620-76-C-0013

9. PERFORMING ORGANIZATION NAME AND ADDRESS:
Human Performance Laboratory (Dept. of Psychology)
New Mexico State University
Las Cruces, New Mexico 88003

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS:
61102F 16 2313
2313A4 17 A4

11. CONTROLLING OFFICE NAME AND ADDRESS:
Air Force Office of Scientific Research (NL)
Bolling Air Force Base
Washington, D.C. 20332

12. REPORT DATE: 11 Nov[redacted]77

13. NUMBER OF PAGES: 32 12 34p.

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15. SECURITY CLASS. (of this report): Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

DDC FEB 22 1978 F

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Stroop Task, Selective Attention, Response Competition

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Separate response time measures were obtained for input and output processes in order to determine their relative contribution to Stroop task interference. In Experiment 1 the amount of relevant and irrelevant stimulus information was varied in a Stroop task using a key press response. Experiment II compares the input and output times for color and word identification versions of Stroop tasks while varying the labeling of the response panel. Stroop interference was found to occur in both input and output time measures in both experiments. The results were interpreted as indicating both a perceptual and a response competition basis

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for Stroop interference.

Preface

One of the major problems in the design of man-machine systems concerns the need to present large amounts of information on a screen from which the system operator may extract information selectively. As a result information displays are frequently crowded with text, graphics, and symbols. Future even more complex displays promise to make the situation still more difficult for the operator to handle the incoming data load. Among the problems involved is the need for the operator to acquire and respond to only those aspects of the display which are relevant for some immediate purpose. Information which may be relevant in a few moments must somehow be ignored until needed. Furthermore, the immediately needed information may be at different parts of the screen, or even on different displays. As a result, the operator must not only be unaffected by the irrelevant information but he must hold some of the relevant information in memory as he acquires more, and then he must react appropriately. When he does this successfully, how does he do it? Does he tune out or filter the irrelevant information so that it never becomes part of what gets into memory? Does he pick up all of the information, but somehow encode it into memory so that only the relevant information is retrieved? Does he put it all into memory without differentiation, but retrieves it selectively? Does he process all of it to the point of responding, and then suppress responses to the irrelevant information? Or does he carry out more than one of those activities? A clear answer has very direct, practical consequences in the design of information systems for it would indicate to what kind of process the design should be directed.

A widely used laboratory method for the study of human information processing is that developed by Stroop in 1931. The basic task is one in which the subject is presented with a series of words which are the names of colors.

The words are printed in colored ink such that the actual colors differ from the word-names, e.g., the word, RED, printed in blue. The viewer is required to report the actual color and not the word. It is well-established that the word interferes with color naming. Extensive use of this task and its variations have led to the development of theoretical models which account for the interference. Some of these models account for it in terms of selective attention or filtering of the incoming information. Others explain the interference as a competition of signals for response and a consequent suppression of responses to the irrelevant word signals.

The theoretical problems and the design problems are similar not only in that they are concerned with the same kind of phenomenon, but also because there has not been available a method for fractionating the total human process into that part which is concerned with the pickup, processing, and storage of stimuli and that part which is concerned with the retrieval from storage and the selection of response to signals. Only measures of the total combined effect of all intervening processes have been available. As a result critical tests of theory and of design have not been available, and both theory and design have advanced slowly.

A recent report from this laboratory (NMSU-AFOSR-TR-77-2) of research carried out under this AFOSR project describes a method developed for separating the input from the output processes. The Stroop phenomenon experiments reported in the following pages represent the first applications of the method. Although more research is required, the results are clear in showing that if the research is done, a breakthrough can be anticipated for both the design and the theoretical problems.

Warren H. Teichner
Principal Investigator

Acknowledgements

This research could not have been completed without the diligent efforts of Mr. Larry Gambil, Mr. Kirk Moffitt, and Ms. Julie Goodrich who ran the subjects in these experiments. Acknowledgements are also given to Ms. Nancy Hutchcroft who prepared the figures and Ms. Julie Goodrich who prepared the manuscript.

A special note of gratitude is due to Dr. Warren Teichner whose methodological breakthrough enabled the separate analysis of encoding and response factors in the Stroop task. I am further indebted to Dr. Teichner for his helpful comments and constructive criticisms which stimulated my efforts throughout these experiments.

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Input and Output Processes in the Stroop Phenomenon

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Stroop task interference (Stroop, 1935) refers to the increase in time required to identify colors when they are presented as contradictory color words, e.g., blue letters used to spell the word RED, as compared to control conditions in which the colors are presented in a neutral form such as a series of blue Xs. Stroop interference has been proposed to result from difficulties in stimulus input (Egeth, 1967; Hock & Egeth, 1970; Treisman, 1969) or from difficulties which occur at the point of response (Dalrymple-Alford & Azkoul, 1972; Klein, 1964; Morton, 1969). Input interpretations of Stroop interference suggest that this interference results from attempts to selectively attend and to process only relevant information (Treisman, 1969) or it results from a limited capacity for or the serial processing of information during input (Hock & Egeth, 1970). Output interpretations suggest that there is no interference in the input of stimulus information, rather interference in the Stroop task arises from response competition; responses to the color and the word compete for a single motor outlet (Klein, 1964; Morton, 1969).

Although over the past decade numerous studies have been conducted (e.g., Dalrymple-Alford & Azkoul, 1972; Flower, 1975; Hock & Egeth, 1970; Williams, 1977); none of these studies has been able to determine unequivocally the locus of Stroop interference. Most of the results can be explained equally well by either the processes of selective attention and perceptual conflict or by response competition. For example, although Treisman and Fearnley (1969) and Hock and Egeth (1970) interpreted their results as supporting the attentional and perceptual hypotheses, their results have also been suggested to be in accord with the response competition interpretation

(Dalrymple-Alford & Azkoul, 1972; Dyer, 1973). Similarly, the data of Glumenik and Glass (1970) and Klein (1964) have been used in support of the selective attention and perceptual encoding interpretations of Stroop interference (Treisman & Fearnley, 1969; Williams, 1977), although their original conclusions were the opposite.

The inability to draw clear conclusions from Stroop studies reflects the absence of an experimental distinction between the effects of interference from response competition and from perceptual processes. The dependent variables which have been used to measure Stroop interference have clearly confounded input and output and, therefore, can only reflect the combined influence of both processes. Apparently, the only study which has attempted to provide separate measures of perceptual and response processes in the Stroop task is that of Hock and Egeth (1970) who used the Sternberg (1969) paradigm. Unfortunately there are a number of difficulties associated with Hock and Egeth's approach (see Dyer, 1973; Williams, 1977). In fact, the Sternberg model deliberately confounds input and output processes, although it provides a separate measure of memory scanning.

A method for separating the temporal aspects of input and output processes has been proposed by Teichner (1977). Teichner's model is based primarily on empirical manipulations and makes only the following limited theoretical assumptions: (1) that input includes all processes leading up to and including the storage of stimulus information into a nonsensory memory; and (2) that input stops and output begins once all of the to-be-stored stimulus items have been stored. He suggests that given a limited duration stimulus display of two or more items, the time from stimulus onset to the first response represents input time plus the time to output the first response. According to his definition of input and output time, the time from the first response to the second and each successive response contains only output time. An output measure, independent of input time, is obtained by calculating the average time per response (t/r) or all the responses following the first response. This output measure provides an estimate of the time to output the first response. By subtracting the average time per response from the time to the first response an estimate of input time is obtained which is not confounded by the output.

Since Teichner's methodology allows for direct measures of input time separate from output time, the time measures obtained using this method should reflect the locus of Stroop interference. Input time formulated according to Teichner's model does not require the assumption of either serial or parallel processing of incoming information and provides a useful measure under either of these conditions. This is important for testing the locus of interference in the Stroop task since response competition theories (Klein, 1969; Dalrymple-Alford & Azkoul, 1972; Morton, 1969) have assumed parallel processing during input, whereas selective attention or perceptual conflict theories (Hock & Egeth, 1970; Treisman, 1969) have assumed serial processing, or a limited capacity for stimulus input.

If interference in the Stroop task results only from processes occurring during the acquisition of the stimulus, then Teichner's measure of input time should be greater under conditions in which colors are to be identified in the context of incongruent color words, i.e., Stroop stimuli, than under control conditions. The time per response should be comparable for the two stimulus conditions. If Stroop task interference is produced solely by competing responses to the color and word stimuli, the input time will remain constant while time per response for Stroop stimuli will increase over that required for control stimuli. Stroop interference resulting from both perceptual processes and response competition would result in an effect on both input and output measures.

The present experiments examined the Stroop phenomenon using the strategy outlined by Teichner (1977). In order to obtain accurate measures of the time to the first response, as well as interresponse times, the color identification responses of the subjects were obtained from manual key presses rather than from vocal reports. Justification for this procedure rests on studies which have used motoric responses for investigating the Stroop phenomenon and which have obtained reliable Stroop interference and findings highly consistent with verbal studies involving comparable variables (Keele, 1972; Majeres, 1974; Neill, 1977; Schmit & Davis, 1974; and White, 1969). The major difference in the basic effect has been in the magnitude of interference which tends to be smaller with motoric than verbal responses.

Experiment 1

The first experiment factorially manipulated the amount of relevant color and irrelevant word information. Previous studies which have manipulated the amount of relevant stimulus information have had mixed results with some studies showing no effect (Ray, 1974; Golden, 1974), while other studies have found increases in Stroop interference with increases in relevant stimulus information (Williams, 1977). Studies which have found no effect of relevant stimulus information have typically used within-subject designs. Since in those studies subjects experienced all stimulus sets, it is possible that their responses were based upon the largest set size as a point of reference. In support of this possibility, using a between-subjects design, Williams (1977) found increases in Stroop interference with increases in both color and word information. These findings were interpreted as supporting a perceptual conflict locus of Stroop interference.

She indicated, however, that the findings could be accounted for by response competition if increases in irrelevant stimulus information served to increase the difficulty of inhibiting responses to this information.

This first experiment was intended to examine the Stroop effect and its interaction with the amount of relevant and irrelevant stimulus information in order to evaluate the relative contribution of input and output processes. The amount of relevant stimulus information was varied within-subjects, while the amount of irrelevant stimulus information was a between-subject variable. In order to prevent the subjects from using previously encountered large information sets as a point of reference, trials for different levels of relevant stimulus information were blocked and subjects were presented with the stimulus sets in the order of increasing stimulus information.

Method

Subjects. The subjects were 48 undergraduate students who volunteered to participate in the study as partial fulfillment of a methodology requirement for an introductory psychology course.

Apparatus and Stimuli. The stimuli consisted of nine decks of 6 x 9 inch (15.24 x 22.86 cm) white index cards. Each deck contained 13 Stroop cards in which color names were printed in incongruent colors of ink, and 13 matched control cards in which strings of Xs, the same length as the color words on the Stroop cards, were printed in the same colors of ink. Both Stroop and control cards contained four stimulus colors per card. One Stroop card and its matching control card per deck served as practice cards.

The stimulus decks varied in the amount of relevant color information (2, 4, or 6 equiprobable colors) and irrelevant word information (2, 4, or 6 equiprobable color words). Stimulus items on the cards in the two-color and two-word decks were drawn from the set of colors/color words, RED and

GREEN. For the four-color and four-word decks, the stimulus items were taken from the color/color word set, BLUE, GREEN, RED, and YELLOW. The colors/color words ORANGE and BROWN were added to these colors to form the set from which items in the six-color and six-word decks were drawn. All stimulus items for the deck were drawn randomly from the appropriate color/color word set with the constraint that all colors/color words in the deck be equiprobable.

The nine stimulus decks combined the amounts of relevant and irrelevant information factorially so that there were three decks of cards at each level of irrelevant information (2, 4, or 6 color words) and these decks in turn varied in the amount of relevant information (2, 4, or 6 colors). For illustration, the stimulus deck for the two-word and four-color condition had Stroop cards with four color words taken from the set of RED and GREEN. These color words were printed in incongruous colors of ink chosen from the color set of RED, GREEN, YELLOW, and BLUE. The matching control cards contained four strings of Xs colored in the same colors of ink as used in the Stroop cards.

The stimuli were presented to the subject tachistoscopically. The cards were placed approximately 26 inches from the eyes of the subject; the stimulus array subtended approximately 12.2° of visual angle.[1] Responses were made on a 3 x 4 inch keyboard which contained six response keys arranged in a 2 x 3 matrix. The apparatus provided digital time measures from stimulus onset to each button press response.

Procedure. The amount of irrelevant word information (2, 4, or 6 color words) and response instructions (successive or simultaneous) was varied

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1 As no head rest or chin rest was used the distance of the stimuli from the eyes varied slightly from subject to subject depending on seating position.

between subjects with eight subjects per group. The amount of relevant color information (2, 4, or 6 colors) was a within-subject variable and was presented to subjects in a blocked manner in the order of increasing relevant stimulus information. That is subjects received the two color stimulus deck followed by the four and then the six color decks. The Stroop and control cards were presented in a random order within each deck.

At the beginning of the experimental session the subject received verbal instructions as to the color correspondence of the response buttons. These response panel instructions were given either simultaneously, with all six color response keys being identified prior to the presentation of the two color stimulus deck, or successively with the response keys being identified as they were required for response to the relevant color information in the subsequent stimulus deck. Subjects received either simultaneous or successive response panel instructions prior to the presentation of each of the three stimulus decks. After each instructional period they were given verbal test trials in which they were required to identify the response keys associated with the verbally presented colors until they reached the criterion of ten consecutive correct identifications.

As soon as the subjects reached the criterion of ten consecutive correct identifications, they were presented with the stimulus deck appropriate for their experimental condition. Each subject was presented with three stimulus decks, one each of a two color, four color, and a six relevant color deck, consisting of 26 stimulus presentations per deck. The first two of these stimulus presentations were used for practice to ensure that subjects understood the instructions and the task.

At the beginning of each stimulus presentation a 50-millisecond auditory warning signal was presented. A 100-millisecond presentation of a fixation point followed the occurrence of the warning signal by 500 milliseconds. The fixation point was placed so as to correspond with the first letter in the first stimulus item on the subsequently presented stimulus card. The presentation of the stimulus card overlapped the presentation of the fixation point by 30 milliseconds. The presentation duration of each stimulus card was 1000 milliseconds.

Subjects were instructed to push the response keys which corresponded to the colors of ink which were presented on each trial. They were told to respond as quickly and as accurately as possible. On each trial, the number of responses made and response accuracy were recorded along with the time from stimulus onset to the first (S-1) and the last response.

Results

The response times obtained from the subjects were used to calculate three dependent time variables; total time, input time, and time per response. Total time was based on the time from stimulus onset to the last response made to that stimulus. The output time measure, time per response (t/r) was calculated by dividing the difference between the time to the first response and the time to the last response by the number of responses minus one. Input time was then obtained by subtracting the time per response from the time to the first response. The three time measures and the number of correct responses were obtained for each stimulus trial and were then averaged over the 12 stimulus trials in each condition. Analyses of variance were conducted on each of these four variables.

The four dependent variables of interest are presented in Figure 1 as a function of the type of stimulus, Stroop or control, and the amount of relevant stimulus information, defined in terms of the number of colors in the set from which the stimulus items were chosen. As seen in Figure 1a, there

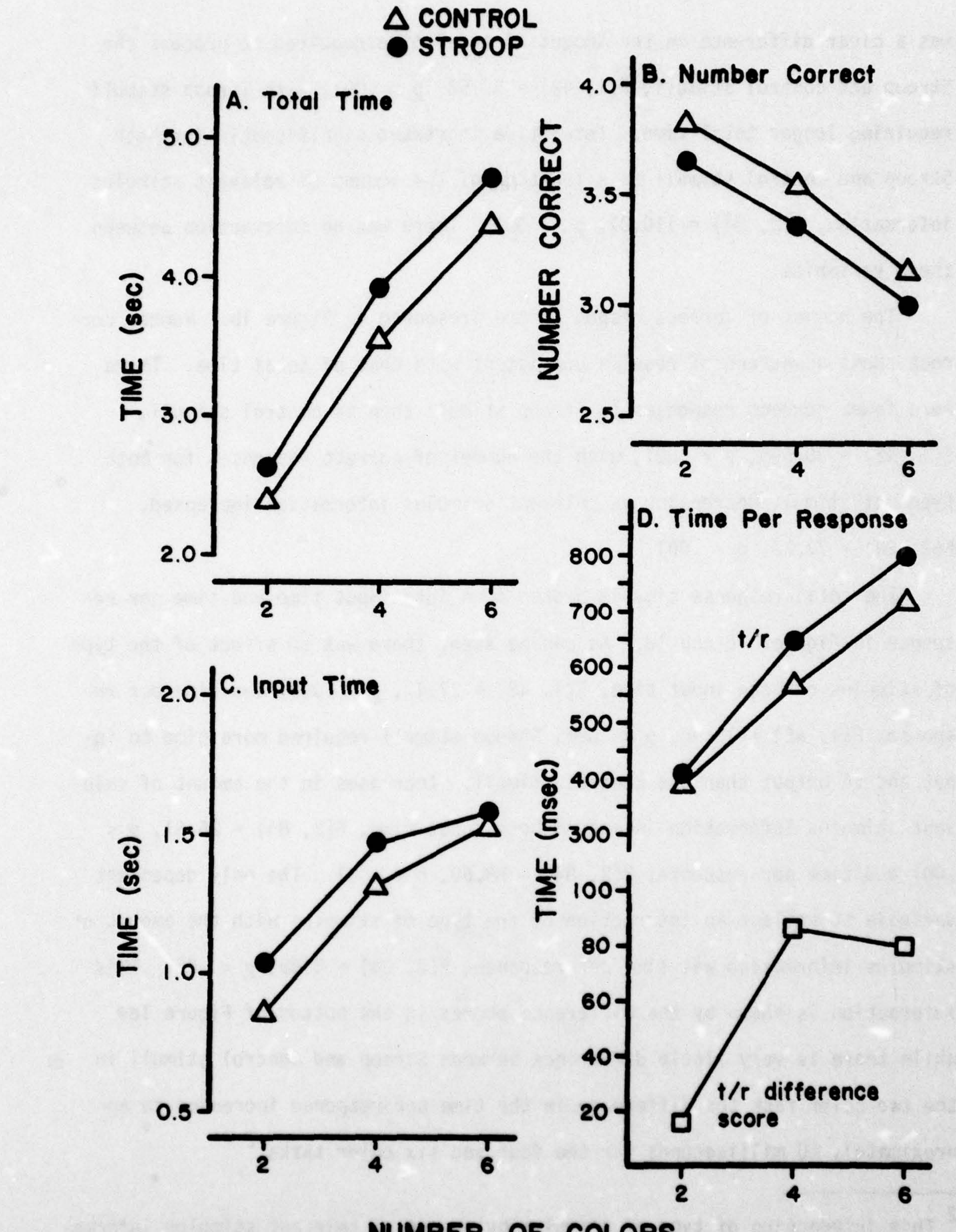

Figure 1. Mean total time, number correct, input time and time per response for Stroop and control cards as a function of the number of colors in the relevant stimulus set.

was a clear difference in the amount of total time required to process the Stroop and control stimuli, $F(1, 42) = 53.58$, $p < .001$, with Stroop stimuli requiring longer total time. Total time increased significantly for both Stroop and control stimuli as a function of the amount of relevant stimulus information, $F(2, 84) = 110.07$, $p < .001$. There was no interaction between these variables.

The number of correct responses are presented in Figure 1b. Number correct shows a pattern of results consistent with that of total time. There were fewer correct responses to Stroop stimuli than to control stimuli, $F(1, 42) = 38.505$, $p < .001$, with the number of correct responses for both types of stimuli decreasing as relevant stimulus information increased, $F(2, 84) = 77.72$, $p < .001$.

The total response time is broken down into input time and time per response in Figures 1c and 1d. As can be seen, there was an effect of the type of stimulus on both input time, $F(1, 42) = 27.17$, $p < .001$, and time per response, $F(1, 42) = 18.98$, $p < .001$; Stroop stimuli required more time to input and to output than the control stimuli. Increases in the amount of relevant stimulus information increased both input time, $F(2, 84) = 26.81$, $p < .001$ and time per response, $F(2, 84) = 88.60$, $p < .001$. The only dependent variable to reflect an interaction of the type of stimulus with the amount of stimulus information was time per response, $F(2, 84) = 3.89$, $p < .05$. This interaction is shown by the difference scores in the bottom of Figure 1d. While there is very little difference between Stroop and control stimuli in the two color task the difference in the time per response increases to approximately 80 milliseconds for the four and six color tasks.[2]

[2] This interaction of type of stimulus by amount of relevant stimulus information has been replicated in a further experiment which will not be reported.

Subjects who were successively presented with response panel instructions took an average of 1.052 seconds for stimulus input. This time was significantly less, $F(1, 42) = 9.05$, $p < .01$, than the average input time required for subjects given simultaneous instructions, 1.546 seconds. The method of response panel instruction interacted with the amount of relevant stimulus information such that more correct responses were made by subjects given successive instructions than those given simultaneous instructions for the task with two relevant stimulus colors. On the other hand, in the four and six color tasks, subjects made fewer correct responses when given successive instructions than when given simultaneous instructions, $F(2, 84) = 4.50$, $p < .05$.

Discussion

The results of this experiment showed that Stroop stimuli required significantly more input and output time than control stimuli. If increases in input and output time for Stroop stimuli, as compared to control stimuli, are interpreted as respectively reflecting difficulties in perceptual processing and response processing, the findings indicate that Stroop interference results from both processes. The contribution of selective attention or perceptual conflict to Stroop interference was essentially constant across all stimulus conditions. Interference effects resulting from response competition on the other hand were larger than the input effects and were more sensitive to variations in the Stroop task.

The time to output each response increased faster for Stroop stimuli than for control stimuli as the amount of relevant stimulus information increased from two to four colors. Since the number of possible responses varied in a one-to-one correspondence with changes in the size of the relevant stimulus set, the present findings may reflect increases in output interference with increases in the number of potential responses. Taken in this light, these findings imply that at least up to a point, four or six responses, the more alternative responses involved the greater the disruptive effect of the irrelevant information.

Experiment 1 found no effect of the amount of irrelevant word information. Such an effect was found by Williams (1977) using verbal responses and the equivalent of the present total time measure. This effect was small in comparison to the effects of relevant stimulus information. While unexpected, the lack of an effect of the amount of irrelevant stimulus information may be due to reductions in the magnitude of Stroop interference typically associated with motor as compared to verbal responses. The findings of the present study in conjunction with that of Williams (1977), however, indicates that the amount of irrelevant stimulus information plays a limited role in Stroop task interference compared to the effect of relevant stimulus information.

Experiment II

Stroop research has shown that Stroop interference is significantly affected when the response demands of the Stroop task are changed. The reverse Stroop task represents one response variation of the traditional Stroop task. In the reverse Stroop task, subjects are presented with color words printed in incongruous colors of ink and are asked to read the words rather than to identify the colors of ink. Previous research has shown that while interference from the irrelevant stimulus information is less in the reversed Stroop task than in the traditional Stroop task, there is an increase in time for reading words when presented as Stroop stimuli as compared to reading words under control conditions (Dyer & Severence, 1972; Gumenik & Glass, 1970; Nealis, 1974; Stroop, 1935).

As found in Experiment I, interference in the traditional Stroop task results from difficulties in stimulus input as well as output. Since the reverse Stroop task involves a change in response requirements, but not in stimulus information, it can be anticipated that the amount of input interference in the reverse Stroop task will be comparable to that of the traditional Stroop task. Differences in the amount of interference generated by the two tasks are expected to result from differences in output interference.

The second experiment attmepted to investigate input and output interference in a traditional as well as in the reverse Stroop task. In order to further examine the contribution of response competition in the traditional as well as the reverse Stroop task the labeling of the response panel was varied so as to be compatible or incompatible with the response demanded by the tasks.

Subjects. Thirty-two undergraduate volunteers from an introductory psychology course served as subjects.

Stimuli and Apparatus. The apparatus for this experiment was identical to that used in the previous experiment with the exception of the response panel. For half of the subjects the keys on the response panel were labeled with typewritten words which indicated the colors to which the buttons corresponded. This was the word labeling condition. For the remaining half of the subjects, the response buttons were labeled with patches of colored ink which corresponded with the colors of ink used in the stimulus cards.

The stimulus deck for the color response task in this experiment was the six-color, six word stimulus deck from the previous experiment. The word response stimuli consisted of the 13 Stroop cards from the color response stimulus deck and 13 matching control cards which presented the same color words as used in the Stroop cards, printed in black ink.

Procedure. The response required of the subject, word or color identification, and the type of stimulus card, Stroop or control, were within-subject variables. There were four groups of eight subjects each. Two of these groups made their responses on keys which were labeled with color words typed in black ink. The response panel for the remaining experimental groups was labeled with color patches corresponding to the color words. The order of presentation of the word and color identification tasks was varied so that half of the subjects in each label condition received the color task first and the remaining half received the word task first.

Subjects received 26 trials on the word and 26 trials on the color identification task. The initiation of a trial began with a 50-millisecond warning signal followed by the fixation point, and a 1000-millisecond stimulus duration.

As in the previous experiment subjects were instructed to respond as quickly and accurately as possible to the colors or color words which were presented on each trial. Responses were made by depressing the response buttons whose labels corresponded to the colors/color words presented on that trial. Number of responses, response accuracy, and the time from stimulus onset to the first and last responses were recorded for each trial.

Results

The four dependent measures obtained are shown in Figure 2 for the Stroop and control stimuli in the word identification and color identification tasks. Stroop stimuli required significantly longer total time (Figure 2a) than did control stimuli, $F(1, 28) = 24.88$, $\underline{p} < .001$ with word identification taking less total time than color identification $F(1, 28) = 44.75$, $\underline{p} < .001$. The required response and the type of stimulus interacted so that the difference in total time between Stroop and control stimuli was greater in the color response task than in the word response task, $F(1, 28) = 5.89$, $\underline{p} < .05$.

The number of correct responses (Figure 2b) was less for Stroop than for

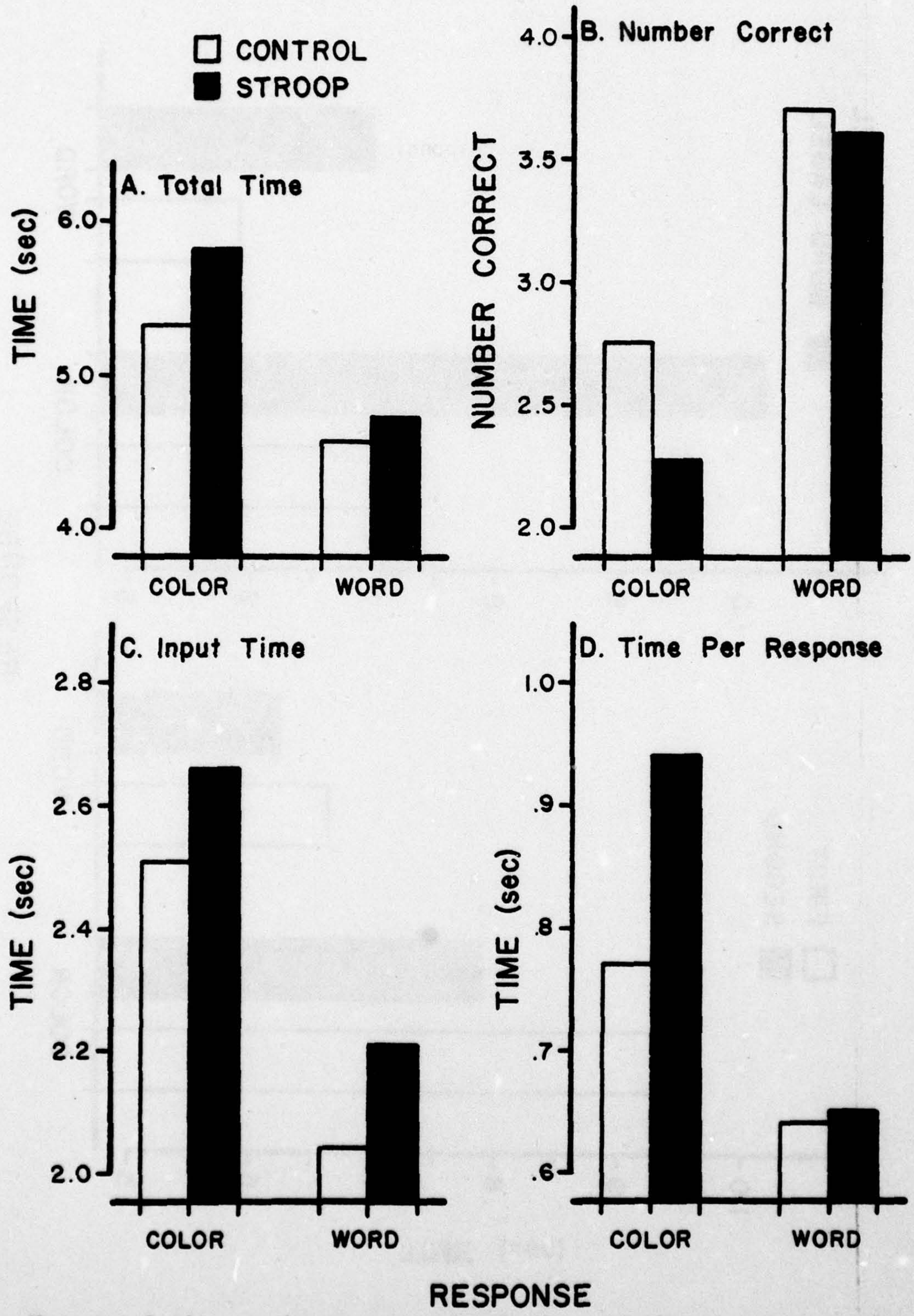

Figure 2. Mean total time, number correct, input time and time per response for Stroop and control cards as a function of the response requirements of the task.

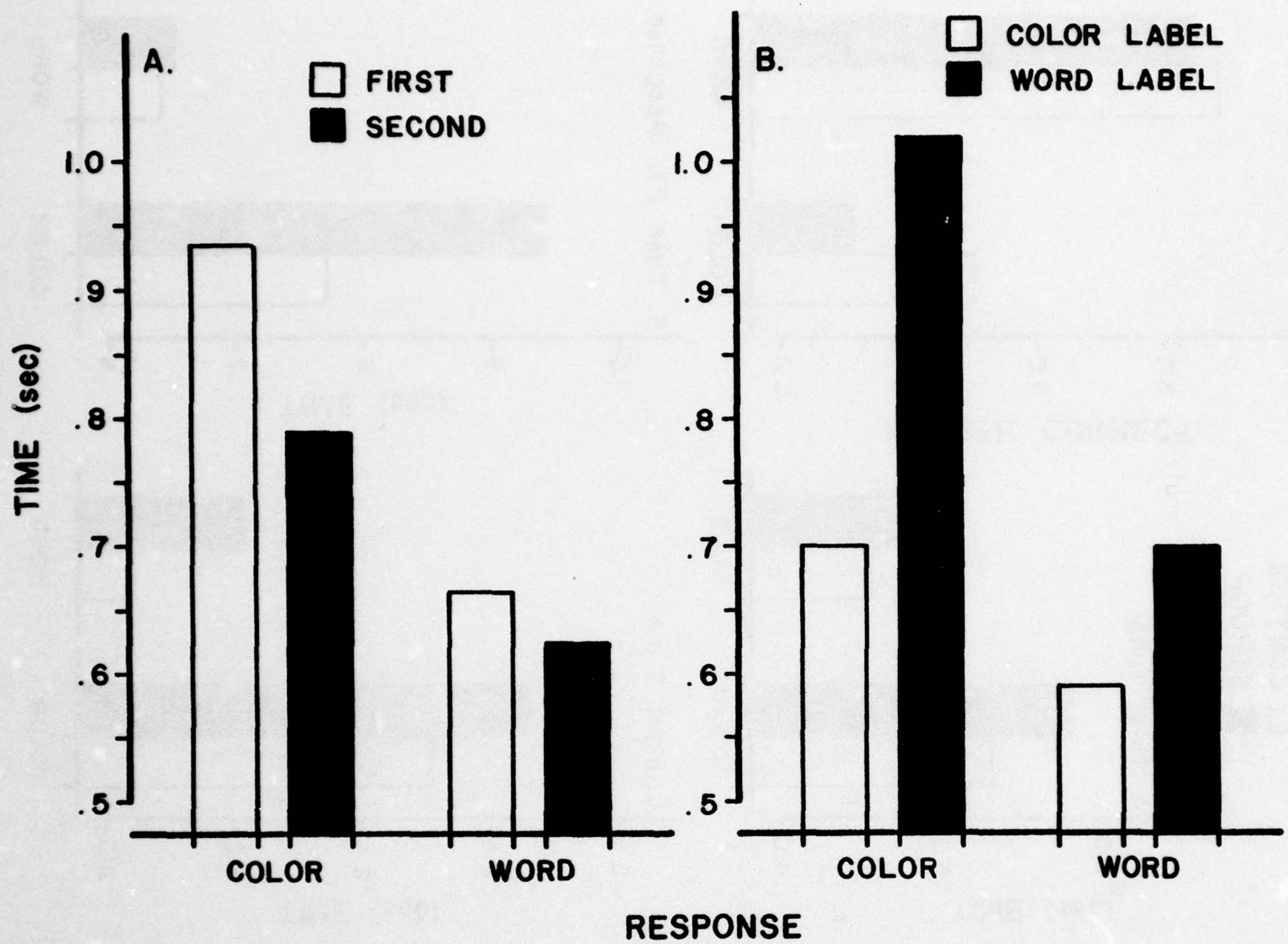

Figure 3. Mean time per response for the color and word response task presented as a function of the order of presentation of the tasks and as a function of the response panel labeling.

control stimuli, $F(1, 28) = 38.50$, $p < .001$, and for the color response task as compared to the word response task, $F(1, 28) = 38.97$, $p < .001$. Also there was a greater difference between Stroop and control stimuli in the number of correct responses when the required response was color identification as compared to word identification, $F(1, 28) = 23.282$, $p < .001$.

Input time and time per response are shown in Figures 2c and 2d. Both measures reflect significantly longer processing times for Stroop than for control stimuli, $F(1, 28) = 10.42$, $p < .001$ and $F(1, 28) = 8.16$, $p < .001$ respectively, and longer times for the color response task than the word response task, $F(1, 28) = 21.43$, $p < .001$ and $F(1, 28) = 33.41$, $p < .001$ respectively. The interaction between the type of stimulus and the response required by the task was significant only for time per response $F(1, 28) = 4.60$, $p < .05$. As with total time, the difference in time per response between Stroop and control stimuli was larger for the color than the word response task.

The order of presentation of the task interacted with the required response to affect the time per response, $F(1, 28) = 5.78$, $p < .05$, see Figure 3a. The time per response for the word response task was essentially the same regardless of whether subjects received this as their first or second task. Time per response for the color task decreased when the color task was preceded by the word response task. The labeling of the response panel also affected time per response but not the other time measures, Figure 3b. Subjects whose response keys were labeled with typewritten words had a significantly greater time per response than subjects whose response panel was labeled with colored patches, $F(1, 28) = 5.213$, $p < .05$. The labeling of the response panel interacted with the required response, $F(1, 28) = 7.27$, $p < .05$, such that word labels on the response panel produced a larger increase

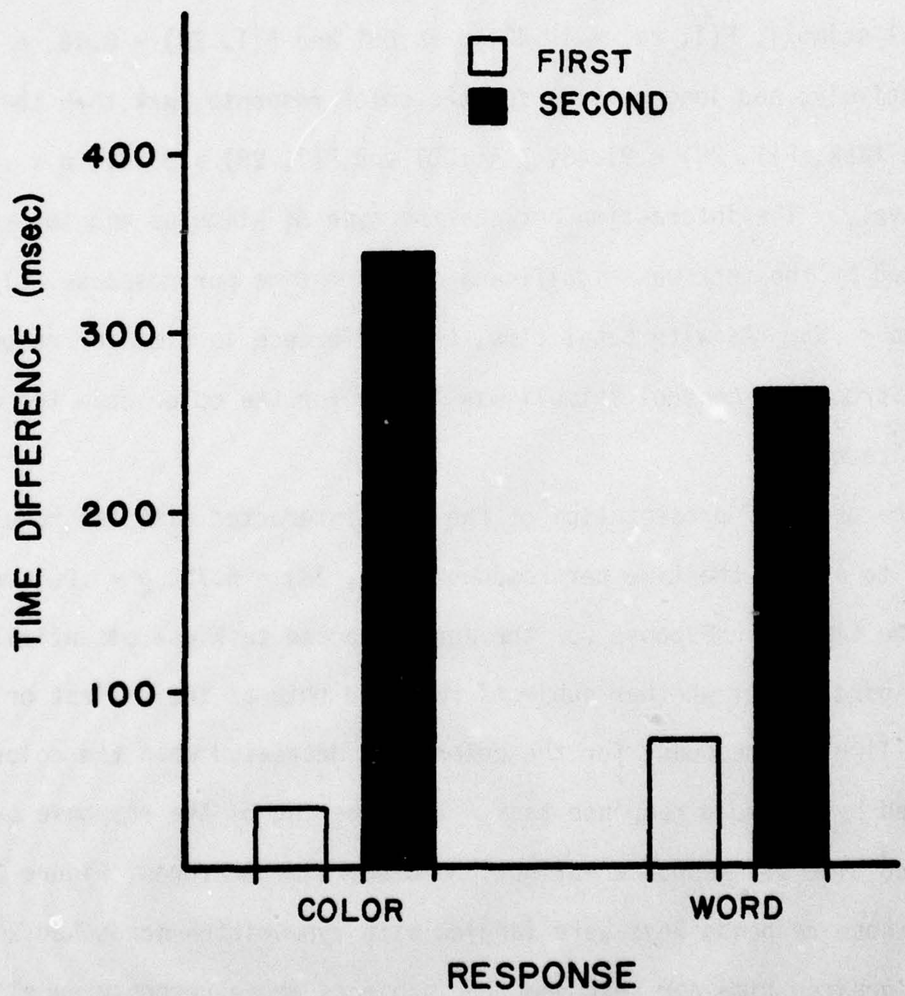

Figure 4. Average difference in input time between Stroop and control stimuli presented as a function of the order of task presentation and the response requirements of the task.

in the time per response for the color task than for the word response task.

Differences between Stroop and control stimuli in input time are presented in Figure 4 as a function of the order of task presentation and the response required by the task. As can be seen differences in input time were greatly increased for both the color and word tasks when these tasks were preceded by a task requiring the opposite response. The increase was greater for the color than the word task. The interaction of task order and response was significant $F(1, 28) = 6.07$, $p < .05$.

Discussion

Stroop interference was found for both the traditional and the reverse Stroop tasks. As with previous studies (Dyer and Severence, 1972; Gurmenik and Glass, 1970; Nealis, 1974; Stroop, 1935) this interference in terms of total time was found to be greater for the traditional than for the reverse Stroop task. When total time was broken into input and output measures it was clear that the decrease in Stroop interference was due to a decrease in output interference rather than interference which occurred on the input side.

The above findings provide support for previous interpretations of interference in the reverse Stroop task. Interference in the reverse Stroop task has been used as evidence for the difficulty in attending to one stimulus attribute while screening out another (Dyer and Severence, 1972) since it was believed to indicate that attention cannot be focused on the color or word attribute of the Stroop stimulus to the exclusion of the other attribute. The current findings of no differences in input interference for the two tasks suggest that the perceptual distractibility of irrelevant words and colors in Stroop stimuli is equivalent.

The finding of a difference in output interference between the traditional and reverse Stroop tasks is in accord with response competition theories of Stroop interference (Morton, 1969; Nealis, 1974; Kline, 1964). These theories suggest that interference in the Stroop task will only occur when the subject completes the processing of the irrelevant information prior to the completed processing of the relevant information. Interference arises presumably because the subject is required to inhibit his response to the irrelevant information in order to respond to the relevant information. Support for the slower processing of color than word information is provided by studies which have found word recognition to be faster than color identification (Lund, 1927) and from our examination of input time and time per response for the control stimuli in the present experiment which indicates that word stimuli are processed more quickly than color stimuli in both input and output. Therefore, assuming that word information is processed at a faster rate than color information, irrelevant words should be more disruptive during output than irrelevant colors.

The labeling of the response panel with words acted to increase the time per response for the color response task to a greater extent than for the word response task. The labeling of the response panel, however, did not interact with the type of stimulus. This finding is contrary to that of Pritchatt (1968) who found increased Stroop interference when response keys were labeled with words. However, Pritchatt reported the total response time to 36 stimuli which in comparison to time per response might be expected to magnify any differences.

Results from Experiments 1 and 2 suggest that Stroop interference in input is less sensitive to the experimental manipulations used than is time per response. The only factor which served to affect the amount of Stroop interference in input was the order of task presentation in Experiment 2. When subjects received either a traditional color response Stroop task or a reverse word response Stroop task as their first task, input interference was substantially less than if the subjects had either one of these tasks before the other. The presentation of an initial task in which either color or word information is relevant and the remaining stimulus dimension is irrelevant apparently changes the relative salience of these dimensions in a subsequent task in which the relevancy of these dimensions are reversed. Subjects may develop a set for responding to one dimension while reducing susceptibility of response to the other. This set for the reception of stimulus information interferes with stimulus processing in the transfer task. These results are in accord with data in the area of concept formation which have found that subjects who are transferred to tasks in which a previously irrelevant stimulus becomes relevant have less of a tendency to attend to this dimension (Gelfand, 1958).

General Discussion and Conclusions

The findings of the present study and the technique used for separating input and output processes in the Stroop task have implications for future studies and modeling of the Stroop phenomenon. They suggest that existing response competition theories (Klein, 1964; Morton, 1969) may well be applicable to that interference which occurs in the output while perceptual conflict or selective attention theories may be applied to the input interference (Hock and Egeth, 1970; Treisman, 1969). Some of the assumptions of these theories may be unnecessary as the theories have been attempting to explain data which was produced by a combination of both input ant output interference. It is necessary, therefore, that these models be reexamined with further studies which separate input and output processes.

Input interference in the Stroop task may be modeled as the time required to focus attention on one stimulus attribute while attempting to block attention to another, or as the time required to process both color and color word stimuli in a limited capacity or serial processing system. If Stroop interference in input is due to a limited capacity or serial processing system, equivalent increases in Stroop interference should result from all increases in stimulus information. However, the present study and that of Williams (1977) show that increases in irrelevant word information do not increase Stroop interference to the same extent as comparable increases in relevant color information. Furthermore, the current study indicates that increases in relevant stimulus information and, consequently, the number of potential responses affects output interference in the Stroop task rather than input interference. These findings cast doubt on the conceptualization of Stroop task interference as due to the serial processing of information during input.

The interpretation of input interference in the Stroop task resulting from attempts to analyze certain stimulus attributes selectively while attempting to gate others (Treisman, 1979) is supported by the relatively constant level of input interference in the present studies. All of the Stroop stimuli in the present experiments required the subjects to contend with two stimulus attributes while in the control stimuli only one attribute was present. The time required to attend to one attribute while screening out the other for the Stroop stimulus would be expected to be relatively constant unless something was done to affect the relative attensity or attention catching value of these attributes, i.e., inducing an attentional set. While the present findings support a selective attention model of input interference, it should be noted that attempts to direct attention to relevant stimulus attributes while gating irrelevant attributes were not totally successful as Stroop interference occurs in output as well as input measures.

There are many different versions of response competition theories (Dyer, 1973). The major underlying assumption of most such models is that

Stroop interference results from the processing of response irrelevant information at a faster rate than response relevant information. As a result the irrelevant information reaches the response initiation stage prior to the relevant information. As previously discussed the present study provides support for the response competition theories as they are applied to output interference. In order to differentiate other assumptions underlying different response competition models further research which examines critical variables underlying these models needs to be conducted. In order for this research to have meaning for response competition models it is necessary that the dependent measures be unconfounded and output interference in the Stroop task be measured separately from input interference.

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